National Aeronautics and
Space Administration

Educational Product	
Educators & Students	Grades 3–12

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Educational Brief

CASSINI SCIENCE INVESTIGATION

Waves and Interference

Objective

To allow students to experience wave interference with their own senses.

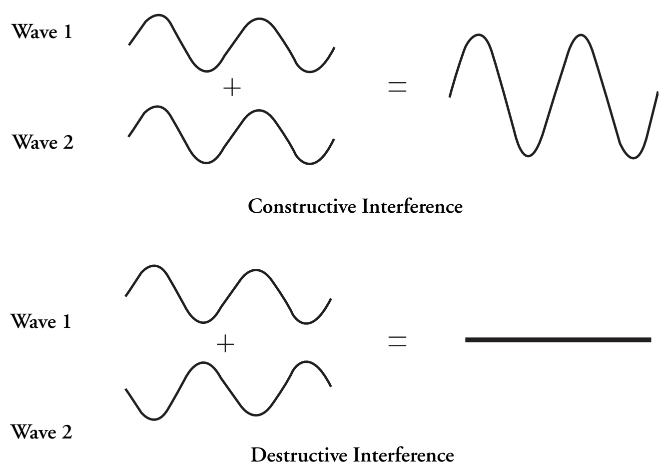
Time Required: 1 hour

Saturn System Analogy: Cassini's Composite Infrared Spectrometer (CIRS) uses the interference of electromagnetic radiation in the infrared region of the spectrum to precisely measure the chemical compositions of planetary atmospheres.

Keywords: Amplitude, Constructive/Destructive Interference, Electromagnetic, Interference, Sound, Waves

MATERIALS

- Cassette or CD player, preferably stereo and adjustable for left–right balance (a "boombox" is ideal).
- Homemade cassette recording of telephone dial tone (multiple sets with minimum duration 15 seconds, or better, a single recording of two minutes or longer). *A better but more expensive alternative is a commercial cassette or CD with a single-frequency tone that can be played. These are available for setting recording levels [CD→cassette] and setting stereo equalizer levels, and can sometimes be found on CD player lens-cleaning disks. An electronic keyboard can generate the necessary tone for recording on a cassette. Lastly, a 12VDC piezo buzzer (e.g., Radio Shack no. 273-059, about $3) can be connected to a 9V battery to generate a continuous high-pitched tone. Depending on the acoustics of the room, a low pitch or a high pitch may demonstrate the phenomena more definitively. Experiment in advance with both.*



Interfering waves may combine constructively (top part of the illustration) or destructively (bottom part). Waves may only partially interfere with the sum of the amplitudes being somewhere between totally constructive or totally destructive interference.

Discussion

All waves exhibit interference phenomena, the effects of their passing through one another as they travel. It is easy to see water-wave interference as ripples cross each other in places they have extra-high peaks or extra-low valleys (high amplitude) where individual wave-peaks or wave-valleys cross paths. In other places, the water surface may briefly be smooth and flat where a peak meets a valley and their sum is zero (zero amplitude). Water waves and light waves (in fact, all electromagnetic waves from long-wave radio through light to x-rays and gamma rays) are transverse waves, exhibiting peaks and valleys as they travel along their paths.

Sound waves are longitudinal pressure waves, in which a wave-carrying medium (e.g., air, water, rock, wood) in a volume changes its density (or, equivalently, pressure) as the wave passes through it. In just the same way as the peaks and valleys of a transverse wave combine, pressure waves can combine for increased amplitude (greater density or pressure) or nulling out (matching the average density or air pressure of surrounding volumes) at a particular point. Our ears provide an easy means of finding amplitude maxima and minima when sound waves interfere. This activity demonstrates these effects.

Procedure

Play the tone through either the left or right speaker (only one of them) at a comfortable level so it can be heard around the classroom. Have students walk around the room (they can start by simply circling their desks) listening for changes in sound volume (sound intensity). Explain that sound waves coming from the speaker reflect off the floor, ceiling, walls, desks, and various other objects in the room. Sometimes the waves add up (interfere constructively) and make a louder sound at a particular spot. Sometimes they cancel each other out (interfere destructively) and reduce the sound volume at some other spot. Map the room by having individual children stop at a spot where the tone is loud (or weak).

Repeat the experiment, but have the tone coming from both speakers equally. The pattern will be different because two sets of waves are moving through the room, bouncing off the same objects but with slightly different distances and angles from objects to speakers. The two wave sets are able to interfere with each other and their various reflections at different places.

With either one or two speakers active, have the students listen for differences in volume by changing from a standing position to a kneeling position. This demonstrates the three-dimensional nature of sound wave propagation.

Extension

Take the sound generator out to the playground or open field (an area with few sound reflectors.) Repeat the classroom experiments using one and two speakers. Is the pattern more regular? Is there more or less three-dimensionality to the pattern? What would happen in a large, empty room like a gymnasium? Why don't we notice interference when we listen to voice or music from stereo sound systems?

Science Standards

A visit to the URL http://www.mcrel.org yielded the following standards and included benchmarks that may be applicable to this activity.

9. Understands the sources and properties of energy.

LEVEL I: PRIMARY (GRADES K–2)

Knows that sound is produced by vibrating objects.

11. Understands the nature of scientific knowledge,

LEVEL 1 (GRADES K–2)

Knows that scientific investigations generally work the same way in different places and normally produce results that can be duplicated.

LEVEL 2 (GRADES 3–5)

Knows that although the same scientific investigation may give slightly different results when it is carried out by different persons, or at different times or places, the general evidence collected from the investigation should be replicable by others.

12. Understands the nature of scientific inquiry.

LEVEL 1 (GRADES K–2)

Knows that learning can come from careful observations and simple experiments.

LEVEL 2 (GRADES 3–5)

Knows that scientists use different kinds of investigations (e.g., naturalistic observation of things or events, data collection, controlled experiments), depending on the questions they are trying to answer.

Plans and conducts simple investigations (e.g., formulates a testable question, makes systematic observations, develops logical conclusions).

LEVEL 3 (GRADES 6–8)

Designs and conducts a scientific investigation (e.g., formulates hypotheses, designs and executes investigations, interprets data, synthesizes evidence into explanations, proposes alternative explanations for observations, critiques explanations and procedures).

Establishes relationships based on evidence and logical argument (e.g., provides causes for effects).

13. Understands the scientific enterprise.

LEVEL 1 (GRADES K–2)

Knows that in science it is helpful to work with a team and share findings with others.

LEVEL 2 (GRADES 3–5)

Knows that scientists and engineers often work in teams to accomplish a task.

***Teachers** — Please take a moment to evaluate this product at* http://ehb2.gsfc.nasa.gov/edcats/educational_brief.
Your evaluation and suggestions are vital to continually improving NASA educational materials. Thank you.

Student Worksheet — Waves and Interference

Procedure

Prepare a map of your room, including desks and aisles. Your teacher will play a tone through the speaker of a sound system. Walk around the room listening for changes in sound volume (sound intensity). Mark spots on the map where the sound peaks in loudness (volume or amplitude) and where the sound is at a minimum. You may repeat the mapping with the tone coming from two speakers.

Questions

Equally tall students should compare their maps. Are they the same? Why might they be different?

Students with different heights can compare maps. Are there differences? Why or why not?

If you made single speaker and dual speaker maps, compare them. Are they different? Why?

What would happen if a different pitch (tone) were used?

Can you think of other types of waves that act like sound waves?